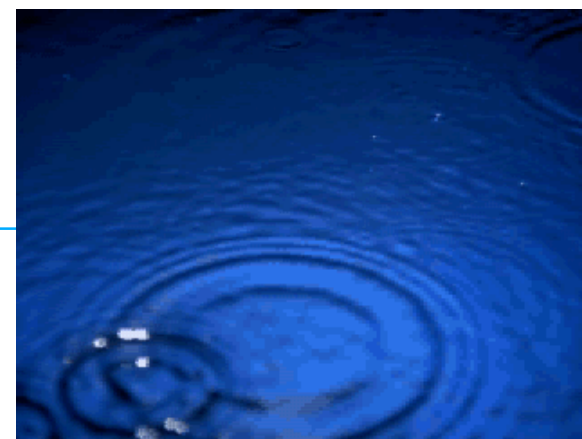


Global Precipitation Measurement

System Definition Review

Mission Requirements

December 6-8, 2005



David Bundas 301/286-5573

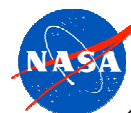
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V

Goddard Space Flight Center



- **L1 Requirements**
 - *Flow from Science*
 - *Allocation to Segments*
 - *Driving Requirements*
- **Level 2 Requirements**
 - *Science Requirements*
 - *Mission-level Requirements*
 - *Element Requirements*
- **Status**



Earth Science Enterprise Science Questions

Variability- I-1 Global Precipitation
Response- III-1 Clouds & Hydrology
Consequences- IV-1 Local Weather
Prediction- V-1 Weather Forecast
V-2 Climate Variation
V-3 Long Term Climate

Direct
Contribution
to
Answering
Science
Questions

GPM Science Objectives

- * **Precipitation Measurement Capability-** advance precipitation measurement capability from space to achieve global sampling
- * **Water/Energy Cycle Variability** advance understanding of the global water/energy cycle and fresh water availability.
- * **Climate Prediction-** improve climate prediction capability.
- * **Weather Prediction-** improve numerical weather prediction skills.
- * **Hydrometeorological Prediction** advance flood-hazard and fresh-water-resource prediction capabilities

GPM Science Drivers

- * **Global Coverage** provide precipitation rates with 3-hour average revisit over 80% of the globe.
- * **Measure** 4-D structure at 5 km resolution of rainfall rates, estimate drop size distribution, and detect snowfall.
- * **Accuracy** - Bias error <10% in instantaneous rain rate at 50 km resolution between S/C and GV data.
- * **Precision** - Random errors <25% at 10 mm/hr and <50% at 1 mm/hr.
- * **Latency** - Deliver science data products within 3 hours of observation time.

NASA Program Constraints

- * **Budget**
- * **Schedule-** LRD of Core S/C shall be December 2010
- * **Partnerships-** Utilize JAXA contributions and coordinate schedules
- * **Lifetime-** 3 years required, 5 year consumables
- * **Reliability** Ps > 0.7 of returning instrument science data for 3 years

Level One Performance Requirements

Science (3.1.1)

Space Segment (3.1.2)

Launch Segment (3.1.4)

Ground Segment (3.1.3)



Level 1 Performance Requirements

Level One Performance Requirements

Science (3.1.1)

- 3.1.1.1** Quantify rain rates and PSD.
- 3.1.1.2** Provide precipitation rates with 3-hour average revisit over 80% of the globe.
- 3.1.1.3** Deliver swath data within 3 hours of observation time.
- 3.1.1.4** Provide rain rate at 50 km resolution, bias < 10% over 90% of the globe.
- 3.1.1.5** Provide rain rate at 50 km resolution, random <25%-50% over 90% of the globe.
- 3.1.1.6** Utilize both active and passive measurement techniques. Use DPR to calibrate passive radiometers.
- 3.1.1.9** Provide analyses of precipitation: instantaneous rate, 3-hour rate, daily accumulation, monthly accumulation, and outreach products.

Instruments (2.4) :

- * Utilize multiple instruments to achieve scope of precipitation observations

Space Based (2.4) -

- * Dual Frequency Precipitation Radar (Provided by JAXA)
- * Multi-channel, Polarized, Conical Scan, Passive Microwave Radiometer

Ground Based (3.1.1.8) -

- * Utilize ground-based instrumentation for in-situ measurement used for satellite algorithm refinements.

Space Segment (3.1.2)

- 3.1.2.1** The NASA developed space assets shall have a design life of 3 years with consumables sized for 5 years.
- 3.1.2.2** Ensure that the high frequency channels of GMI have a design life of 14 months.
- 3.1.2.3** The NASA developed space assets, excluding LV, shall have Ps > 0.70 to return science data.
- 3.1.2.4** Coordinate orbit architecture of NASA S/C with partner constellation S/C.
- 3.1.2.5.1** Develop a Core S/C that will accommodate the JAXA DPR and NASA GMI.
- 3.1.2.5.2** Develop a constellation S/C that will accommodate the NASA GMI.
- 3.1.2.6** NASA Provided S/C shall meet the Orbital Debris Requirements.

External Agreements (3.2)

- 3.2.1** Space Assets:
Establish domestic and International agreements to access required space assets and data.
- 3.2.2** Ground Assets:
Establish domestic and international agreements to access required ground validation assets and data.

Products and Applications (3.3)

- 3.3.1** produce research, immediate, and outreach precipitation products.
- 3.3.2** Make products available to decision-support systems and processes.

Public Outreach Data Access (3.4) :

- * Engage in an education and outreach program.

Ground Segment (3.1.3)

- 3.1.3.1** Provide ground system and mission operation support services.
- 3.1.3.2** Provide services to capture, process, and deliver science data for science processing.
- 3.1.3.3** Provide a science data processing system.
- 3.1.3.4** Provide a Ground Validation System.

Launch Segment (3.1.4)

- 3.1.4.1** The launch vehicle for the GPM Core Observatory shall be the JAXA provided H2A-202 Expendable Launch Vehicle (ELV).
- 3.1.4.2** The GPM Core Observatory shall be launched from the Tanegashima Space Center (TNSC) Yoshinobu (H-II) Launch Complex located on Tanegashima Island, Japan.
- 3.1.4.3** The NASA provided constellation spacecraft shall be launched on a domestic launch vehicle from a domestic launch site consist with its orbit parameters.



- **(3.1.1.2) Precipitation sampling - Global coverage with 3 hour revisit times**
 - Constellation of satellites, drives orbit definitions for NASA-provided assets
 - Ingest multiple data streams from NASA and domestic and foreign partners
- **(3.1.1.1) Precipitation Measurement**
 - Drop size distribution (DSD) measurement
 - Drives use of dual-frequency precipitation radar (DPR)
 - Drives co-alignment requirements
- **(3.1.1.3) Swath Data Latency - 3 hours**
 - Drives Ground System
- **(3.1.1.8) Ground Based Measurements**
 - Ground-based measurements for satellite algorithm improvement
- **(3.1.1.6) Calibration Standard**
 - DPR/GMI provide the reference for other PMRs in the constellation
 - Drives geo-location requirement
- **(3.1.2.1) Core Observatory Lifetime: 3 years**
 - Overlap of 18 months with NASA Constellation Spacecraft
 - Consumables sized for 5 yrs
- **(3.1.2.3) Reliability requirement is 0.7 for return of instrument data**
- **(2.2) Risk Classification:** Class B mission per NPR 8705.4
- **(3.1.2.6) End-of-Life disposal**

Design-for-demise

Level I Requirements

Mission:	Instrument:
<ul style="list-style-type: none"> ➤ Measurement ➤ Validation ➤ Products ➤ Duration 	<ul style="list-style-type: none"> ➤ Space Based ➤ Ground Based
<ul style="list-style-type: none"> ➤ Launch ➤ Science Data Science ➤ Science Products ➤ Operations ➤ Public Outreach 	

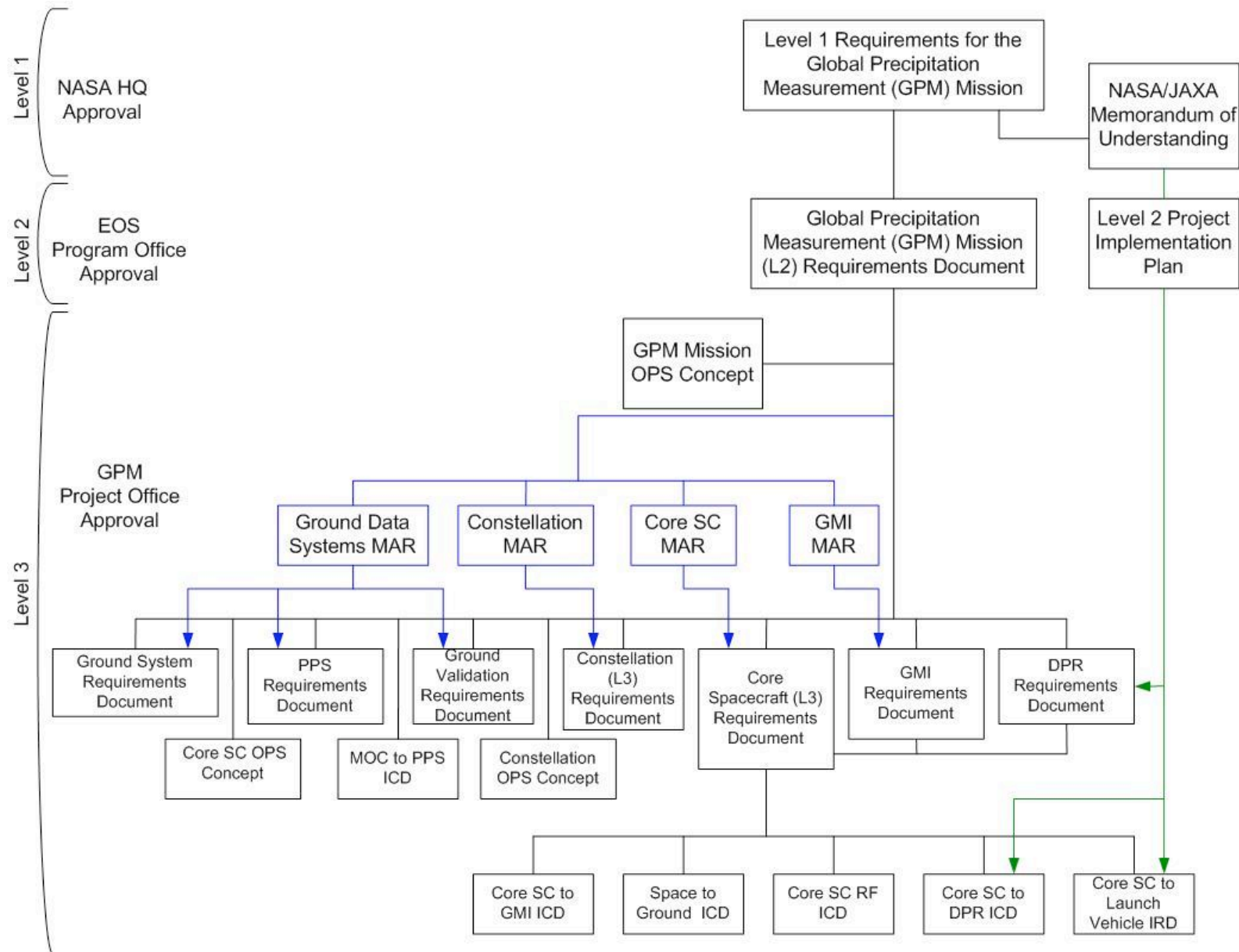
Other Sources

<ul style="list-style-type: none"> ➤ Formulation Study Results ➤ Science Workshops ➤ GSFC Guidelines

Level II Requirements

Science:	Mission:
<ul style="list-style-type: none"> ➤ Precipitation Types ➤ Measurements ➤ Coverage ➤ Frequency & Accuracy 	<ul style="list-style-type: none"> ➤ Data Handling ➤ Payloads ➤ Constellation Design ➤ Calibration & Verification ➤ Outreach
❖Launch Services	❖Process Requirements
Space Segment:	Ground Segment:
<ul style="list-style-type: none"> ➤ Instruments <ul style="list-style-type: none"> - DPR - GMI ➤ Core Spacecraft <ul style="list-style-type: none"> - Performance - Accommodation ➤ Constellation Spacecraft <ul style="list-style-type: none"> - Performance - Accommodation 	<ul style="list-style-type: none"> ➤ NASA Mission Operations <ul style="list-style-type: none"> - S/C Flight Ops - Space/Ground Coordination ➤ Ground Validation & Calibration ➤ Precipitation Processing System <ul style="list-style-type: none"> - Product Development - Data Distribution & Archive





- **(3.1.1) Discrimination between convective & stratiform precipitation types**
- **(3.1.2) Measurement range** - 0.3 to 110 mm/h over land and ocean
- **(3.1.3) Detection of snowfall**
- **(3.1.4) Estimation of drop size distribution of precipitating particles**
- **(3.1.5) Estimation of 3-D latent heat release**
- **(3.1.6) Horizontal resolution** – 5 km between 65°N and 65°S
- **(3.1.7) Vertical resolution** – 0.25 km between 65°N and 65°S
- **(3.1.8) Coverage and Sampling** – average revisit time of 3h or less over 80% of the globe
- **(3.1.9) Accuracy of instantaneous surface rain rates** – biases $\leq 10\%$ at 50 km resolution relative to calibrated ground validation data
- **(3.1.10) Precision of instantaneous surface rain rates** - random errors $\leq 25\%$ at 10 mm/h and $\leq 50\%$ at 2 mm/h at 50 km resolution relative to calibrated ground validation data over ocean. Over land, the requirements relaxes by a factor of two.
- **(3.1.11) Error characterizations of instantaneous surface rain rates, associated radar reflectivity, and microwave brightness temperatures**



- 2.2.1 *Launch Readiness Date - Core Observatory*
 - *Launch Readiness Date December 2010*
- 2.2.2 *Overlap between Core, Constellation*
 - *Launch Constellation within 18 months of Core Spacecraft*
- 2.2.3 *Spacecraft Selection*
 - *Select constellation to meet mission requirements*
- 2.2.4 *Constellation Make-up*
 - *Deals with shared s/c and partnerships*
- 2.2.5 *Mission Assurance Requirements*
 - *Comply with GSFC MAR*
- 2.2.6 *End-of-Life Reentry Requirements*
 - *Design-for-demise*
- 2.2.7 *Use of Metric Units*
 - *Per NPD*
- 2.2.8 *Use of CCSDS Standards*
 - *Standard Data Interface*
- 2.2.9 *Science Data File Transmission*
 - *Requires use of CCSDS File Delivery Protocol (CFDP)*
- 2.2.10 *Data Collection Completeness*
 - *98 % of instrument data to be collected*
- 2.2.11 *Data Collection Efficiency*
 - *95% of on-orbit time in science taking mode after 60 day checkout period*
- 2.2.12 *Space Asset Protection*

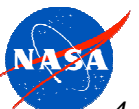
- **4.1.1 DPR Interface Requirements**
- **4.1.2 DPR Lifetime**
- **4.1.3 DPR Reliability**
- **4.1.4 Operating Bands**
- **4.1.5 Horizontal Resolution**
- **4.1.6 Vertical Resolution**
- **4.1.7 Swath Width**
- **4.1.8 DPR Data Rate Allocation**
- **4.1.9 Calibration**



- **4.2.1 GMI Measurement Channels**
- **4.2.2 GMI Interface Requirements**
- **4.2.3 GMI Lifetime**
- **4.2.4 GMI Reliability**
- **4.2.5 GMI Earth Incidence Angle**
- **4.2.6 GMI Contiguous Coverage for Channels 1 through 7**
- **4.2.7 GMI Partial Coverage for Channels 8 through 13**
- **4.2.8 GMI Resolution**
- **4.2.9 GMI Swath Width**
- **4.2.10 GMI Data Allocation**
- **4.2.11 Error Characterization of Level 1 Brightness Temperature Products - Channels 1 through 9**
- **4.2.12 Error Characterization of Level 1 Brightness Temperature Products - Channels 10 through 13**



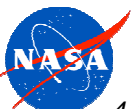
- **(5.3) Lifetime – 3 years with 5 years of consumables**
 - Satisfies L1
- **(5.4) Reliability**
 - Provides a means to evaluate reliability design decisions
- **(5.10.4, 5.10.5) Geolocation of Measurements – DPR, GMI**
 - Needed to relate measurements to models and co-observations
- **(5.5, 5.6) Orbits – Launch, Operational, Maintenance**
 - Defines orbits to satisfy coverage and mission life
- **(5.7) Launch Vehicle Capability**
 - Defines mass to orbit
- **(5.10.X) Instrument Accommodation**
 - Defines technical resources needed by the instruments
- **(5.10.3) Nadir Pointing Accuracy**
 - Needed to support geolocation and co-observations
- **(5.11.X) Communications**
 - Defines uplink, downlink, data allocations



- **(6.3) Lifetime – 3 years with 5 years of consumables**
 - Satisfies L1 requirement
- **(6.5) Reliability**
 - Provides a means to evaluate reliability design decisions
- **(6.11.4) Geolocation of Measurements – GMI**
 - Needed to relate measurements to models and co-observations
- **(6.6) Orbit**
 - Orbit to be selected to satisfy coverage and mission life
- **(6.11.X) Instrument Accommodation**
 - Defines technical resources needed by the payload
- **(6.11.3) Nadir Pointing Accuracy**
 - Needed to support geo-location and co-observations
- **(6.11.12) Communications**
 - Defines uplink, downlink, data allocations



- **Mission Operations:**
 - (7.1.22) Health & Safety - Standard capability
 - (7.1.38) Availability - Ensures ops center is up for critical operations
 - (7.1.15) CMD & TLM - Standard capability
 - (7.1.15-7.1.21) Data Handling and Interfaces - ops co-ordinates all of the assets
 - (7.1.31) Flight Software Maintenance - Standard capability
- **Instrument Operations:**
 - (7.1.20) Commanding
 - (7.1.29) Performance Monitoring
- **Space/ Ground Link:**
 - (7.1.1) Space Network - Continuous Return link for SC HSK/GMI data
 - (7.1.41) Data Loss Allocation
 - (7.1.8) Contingency Operations - Switch to ground if TDRSS is lost



- **Precipitation Processing System**

- (7.2.2) Ingest Data from GPM and Partner data sources
- (7.2.12) Research Products Definition
- (7.2.15) Geolocation of Instrument Data
- (7.2.18) Science Algorithm Support
- (7.2.21) Research Product Latency
- (7.3.1, 7.3.2) Data Distribution and Archiving

- **Ground Validation System**

- (7.4.1) Assessment of Satellite Precipitation Estimates
 - Using ground-based measurements
- (7.4.3.1) Ready for Operations
 - 6 months prior to Core spacecraft launch



- **L1 Requirements Status:**
 - Under review with HQ
 - Signoff occurs prior to GPM MCR in late 2006

- **L2 Requirement Status:**
 - L2 has been reviewed/baselined within GPM Team
 - After updated based on SDR comments, L2 will go into signature cycle
 - L3's are in draft state, signature ready at PDR
 - All L1/L2 Requirements have been Allocated to GPM Elements
 - Traceability from L1 to L2 captured in DOORS
 - Traceability from L2 to L3 captured in Excel spreadsheet
 - As L3's are baselined, they will be imported into DOORS



Day 1 - December 6, 2005

Location: NASA GSFC B16W-N76/80

Time	Section	Event	Presenter
8:30 AM		Logistics & Announcements	Durning
8:35 AM	1	Introduction	Durning/Ho
8:45 AM		Charge to Review Team/RIDs: Purpose & Review Criteria	Ho
8:55 AM		HQ Overview	Neeck
9:10 AM	2	GPM Mission Overview	Durning
9:55 AM	3	Science Requirements	Hou
10:25 AM		Break	
10:40 AM	4	Mission Requirements	Bundas
11:10 AM	5	Mission Architecture	Bundas
11:55 AM		Lunch	
12:55 PM	6	Systems Engineering Processes	Bundas
1:40 PM	7	System Safety and Mission Assurance	Toutsi
1:55 PM	8	External Interfaces	Hwang
2:10 PM	9	Dual Precipitation Radar (DPR) Overview/Requirements	Woodall
2:55 PM		Break	
3:10 PM	10	GPM Microwave Imager (GMI) Overview/Requirements	Flaming/Bidwell
4:10 PM	11	H-IIA Launch Vehicle	Woodall
4:30 PM		Review Team Caucus	
4:40 PM		End of Day 1	

